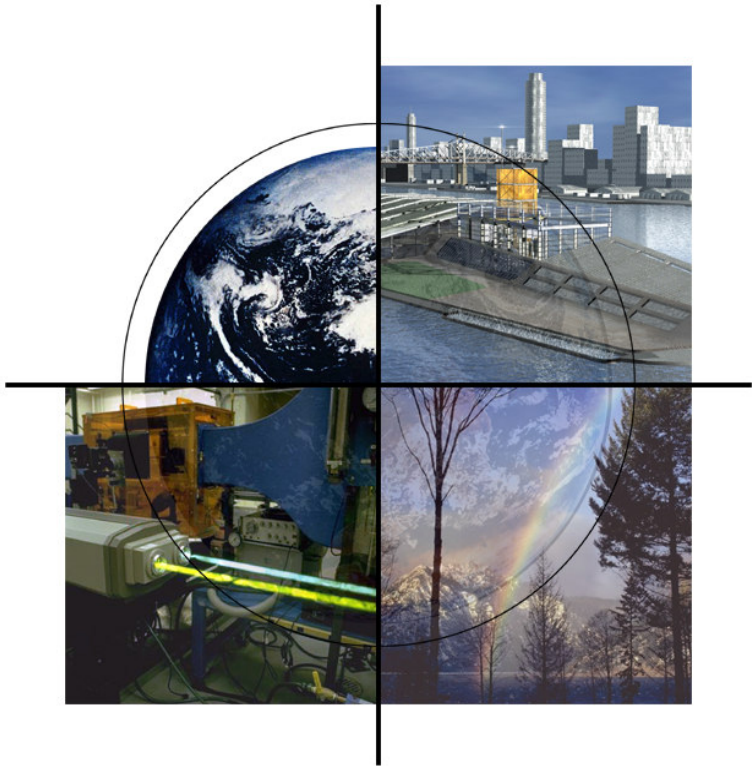
Dynamic Simulation for IGCC Power Plants



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PowerPlantSim 2007
San Diego, California February 19-21, 2007

NETL

enginomix
Integrated Engineering & Economic Solutions

Dynamic Simulation for IGCC Power Plants
Outline of Presentation

- **Motivation and Introduction**
- **NETL "Collaboratory for Process & Dynamic Systems Research"**
- **IGCC DS&T Center Project**
  - Overview of Major Project Phases
  - Phase I: Scoping Study
  - Phase II: Detailed Planning
  - Phases III-V: Development and Deployment

Dynamic Simulation for IGCC Power Plants
Motivation and Introduction

- IGCC emerging as technology of choice for next-generation coal-fired power plants
- Rapidly growing demand for experience with IGCC analysis, operation, and control
- NETL project to develop world-class IGCC Dynamic Simulator & Training Center
  - Under auspices of "Collaboratory for Process & Dynamic Systems Research"
  - Phase I scoping study complete
  - Detailed planning Phase II underway
    - Develop spec for "generic" simulator
    - Establish strategic R&D collaborations, e.g., EPRI, OTS vendor, …
    - Seek strong industry participation from "generic" simulator planning to "custom" simulator deployment, e.g., CoalFleet, …

IGCC Power Plant

IGCC DS&T Center

NETL
Carnegie Mellon
University of Pittsburgh
West Virginia University

NETL Collaboratory

Dynamic Simulation for IGCC Power Plants
Relevance to NETL Mission

- **Only DOE national lab dedicated to fossil energy**
- **Supports major NETL technology programs and in-house R&D focus areas**
  - Gasification, FutureGen, Advanced Research
  - Computational & Basic Sciences, Energy System Dynamics
- **Supports NETL training mission**
  - Provides a trained workforce for the energy industry of the future
  - Promotes R&D and educational initiatives at U.S. universities to advance energy science and technology

Dynamic Simulation for IGCC Power Plants
Enginomix

- **Modeling IGCC systems since 1982**
  - Off-Design Steady-State IGCC modeling work at Stanford using Aspen, sponsored by EPRI 1981-1986
  - Transient modeling of “Simplified IGCC”, GE R&D Center 1986-1988
  - Member ASME PTC 47 (Performance Test Code for IGCC)
- **Original developers of GateCycle**
  - Design and off-design modeling of gas-turbine based power plants
  - Primary combined-cycle design/analysis software used by GE
- **Experts in thermal & chemical systems modeling, economic analysis and engineering software development**
  - Developers and supporters of EPRI TAG Supply® software 1991-9
  - Developing IGCC design & costing software for in-house use at EPRI, including new CO2 capture and compression models
  - Extending IPSEpro® modeling software to support Kalina technology, ORC cycles, IGCC and other advanced energy systems
  - Supporting development of NEA’s Mercurator® Hg emission modeling software

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Collaboratory for Process & Dynamic Systems Research
Overview

- Develops strong NETL-university R&D collaborations that will grow over time to produce increasingly valuable outcomes for DOE and the Nation
- Conducts world-class R&D, training, and education for fossil-energy process and dynamic systems
  - Accelerates R&D on advanced methods and tools
    - High-Fidelity Systems
    - Dynamic Systems
    - Systems Optimization
  - Promotes high quality R&D outreach, growth, and diversity

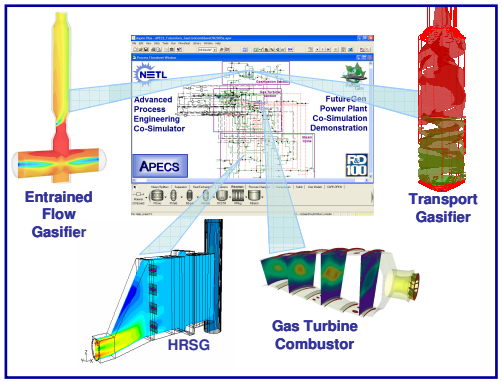
NETL

Carnegie Mellon

University of Pittsburgh

West Virginia University

NETL Collaboratory



APECS Co-Simulation of FutureGen Plant

Collaboratory for Process & Dynamic Systems Research

- **Director**
  - Dr. Stephen E. Zitney, Office of Research & Development, NETL
- **Lead Principal Investigator (PI)**
  - Prof. Richard Bajura, Director, National Research Center for Coal & Energy (NRCCE), WVU
- **Co-PIs**
  - Prof. Lorenz Biegler (CMU, ChE)
  - Prof. I. Grossmann (CMU, ChE)
  - Dr. Rick Phalunas (WVU, NRCCE)
  - Prof. Edward Rubin (CMU, MechE)
  - Prof. Richard Turton (WVU, ChE)
  - Prof. B. Erik Ydstie (CMU, ChE)

- **Projects**
  1. **Development of IGCC Dynamic Simulator & Training Center (TBD - WVU/NRCCE)**
  2. Development of a Multi-Purpose Dynamic IGCC Model for an Energy-Intensive Industry Cluster (Prof. Turton - WVU)
  3. Plant-wide Control and Real-Time Optimization of IGCC Power Plants (Prof. Ydstie - CMU)
  4. Integrated APECS Optimization Strategies for Zero-Emission Power Plants (Prof. Biegler - CMU)
  5. APECS R&D for Fossil Energy Systems (TBD – WVU/NRCCE)
  6. Aspen-based Performance and Cost Models for Power Systems Analysis (Prof. Rubin - CMU)

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Dynamic Simulation for IGCC Power Plants

Major Project Phases

- **Phase I** – Scoping Study (Complete)
- **Phase II** – Detailed Planning (Year 1 CPDSR Project)
- **Phase III** – IGCC Dynamic Simulator Development
- **Phase IV** – Acceptance Testing/Deployment at DS&T Center
- **Phase V** – Establishment/Ongoing Support of DS&T Center
- **Phase VI** – Deployment of Custom IGCC Simulators

	CY05				CY06				CY07				CY08				CY09			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Phase I																				
Phase II																				
Phase III																				
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Phase VI																				

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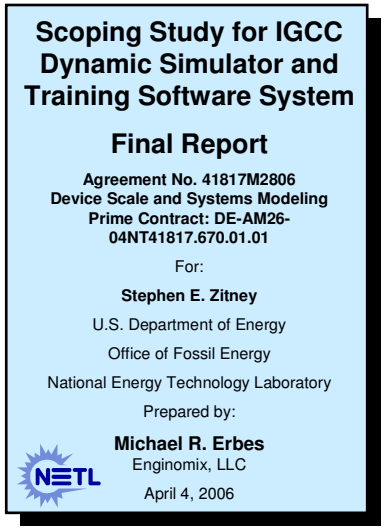
Dynamic Simulation for IGCC Power Plants
Scoping Study

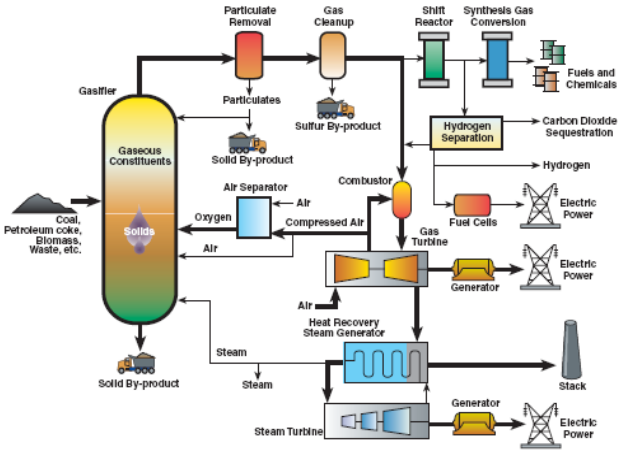
- **Timeframe**
  - October 2005 – April 2006
- **Sponsor**
  - NETL Gasification Program
- **Participants**
  - Michael R. Erbes (Enginomix)
  - Stephen E. Zitney (NETL)
- **Major Accomplishments**
  - Defined simulator requirements and features
  - Evaluated potential OTS frameworks and suppliers
  - Identified DS&T Center requirements and goals
  - Visited AEP and EPRI simulator training centers
  - Developed plan for establishing group of R&D partners and industry participants
  - Determined initial milestones, deliverables, schedule, priorities, risks, and staffing/resource/cost estimates

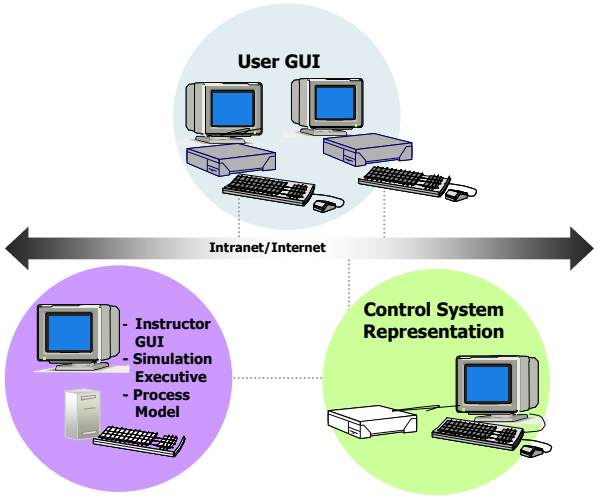


Dynamic Simulation for IGCC Power Plants

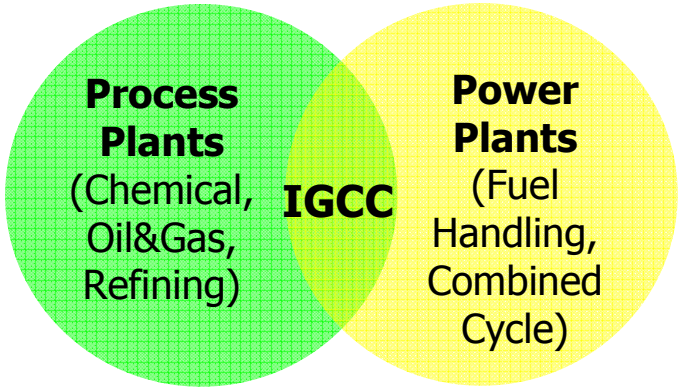
Scoping Study - Simulator Requirements

- Real-time, high-fidelity, dynamic IGCC model (Power + Process)
- Full-scope OTS capabilities
- Full DCS emulation
- Unified platform for model building and training
- Suitable for engineering studies
- Ease-of-use for process/control system modeling
- Flexible and extendable to FutureGen and zero-emission polygeneration plants





Simulator Requirements
Power and Process Modeling Capabilities



- **Gasifier**
  - Slurry and dry feed technologies
- **Air Separation Plant**
- **Gas Cooling & Cleanup**
- **Combined Cycle**
- **Fuel Handling**

Simulator Requirements
Dual Primary Goals

- **Full-Scope Operator Training Capabilities**
  - Malfunctions, Trips & Alarms
  - Scenarios, Trending & Snapshots
  - Startup/Shutdown
  - Load Following, Load Shedding
  - Response to fuel and ambient variations
- **Suitable for Engineering & Systems Studies**
  - Analyzing control strategies (turbine lead, gasifier lead)
  - Leverage existing NETL technology & models
    - Aspen Plus, Dynamics and Custom Modeler
  - Evaluating new technologies
    - Integration of fuel cells
    - Carbon capture and storage
    - Alternate gasifier technologies
    - Advanced cleanup technologies

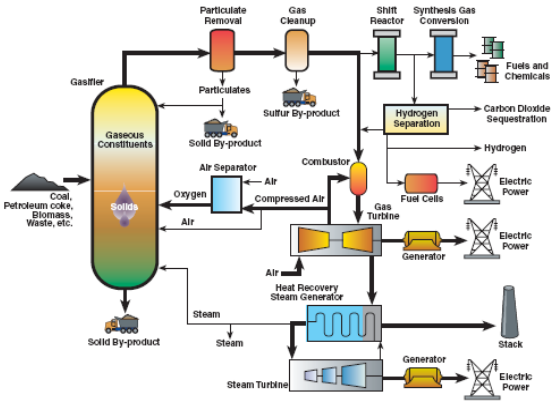
Simulator Requirements
Ease-of-Use and Integrated Modeling Framework

- **NETL Collaboratory**
  - Multiple users across various groups
  - Different levels of expertise
  - Educational and research missions

NETL
Carnegie Mellon
University of Pittsburgh
West Virginia University

NETL Collaboratory

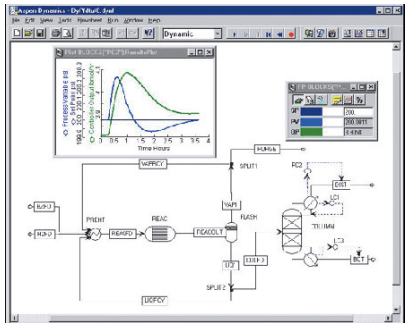
- **Generic IGCC Plant Modeling**
  - Not based on existing IGCC plant or control system
  - Process and control logic to be designed as part of project



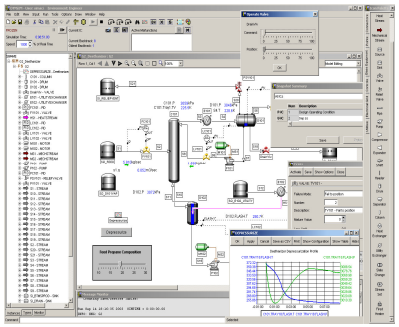
Scoping Study - Simulator Frameworks

- **Major dynamic simulator frameworks evaluated as part of scoping study included:**
  - 3KeyMaster (Western Services)
  - Aspen Dynamics (AspenTech)
  - DynSim (SimSci-Esscor)
  - ProTrax (Trax)
  - SimSuite (GSE Systems)
  - UniSim (Honeywell)

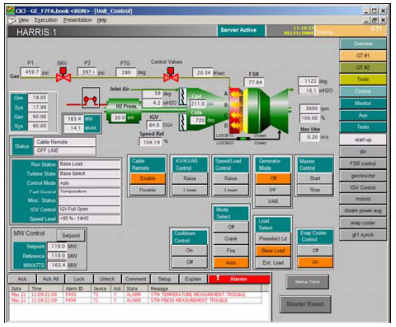
SimSuite at AEP



Aspen Dynamics



DynSim



3KeyMaster

Scoping Study - Training Center Requirements

- **Location**
  - National Research Center for Coal & Energy
  - West Virginia University, Morgantown, WV
- **Demo and Training Services**
  - IGCC plant operation and control demos
  - IGCC plant familiarization training
  - Computer-based training program
  - "Train the Trainer" program
- **Staffing Resources**
  - R&D Manager, IGCC DS&T Center
  - Trainers and support staff
- **Hardware Resources**
  - Standard Windows-based PCs
  - Instructor station, display units, and cabinets

WVU's NRCCE

IGCC DS&T Center

Industry Experts Group
Requirements

- **Promote collaboration between project team and industry**
- **Provide feedback to ensure project team is meeting industry's needs**
- **Promote awareness to power and energy industry**
- **Target members from:**
  - Electric utilities
  - Engineering, procurement & construction (EPC) firms
  - Gasifier suppliers
  - Research institutes
  - Academic researchers

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Phase II – Detailed Planning
Overview

- **NETL Collaboratory Project**
- **Funding: ~$450K**
- **Timeframe: February 2007-December 2007**
- **Staffing Resources**
  - NETL Collaboratory
    - PI, R&D Manager, IGCC DS&T Center, TBD (WVU, NRCCE)
    - Co-PI, Process & Dynamic Systems, Dr. S. Zitney (NETL)
    - Consultant, IGCC Simulation, Dr. M. Erbes (Enginomix)
    - Consultant, Dynamic Simulation, Prof. L. Biegler (CMU)
    - Consultant, Process Control, Prof. E. Ydstie (CMU)
  - EPRI & Other Industry Collaborators

Phase II – Detailed Planning
Primary Tasks

- **Project Planning**
  - Develop detailed project milestones, deliverable, budgets, and schedule
  - Select software/services vendor
- **Simulator Planning**
  - Determine scope of “generic” IGCC process
  - Generate detailed process and control system design
  - Prepare detailed simulator specification
- **IGCC DS&T Center Planning**
  - Hire R&D manager
  - Develop detailed R&D and training services plan
  - Initiate acquisition of hardware/software infrastructure
- **Collaboration Planning**
  - Establish scope of technology collaborations

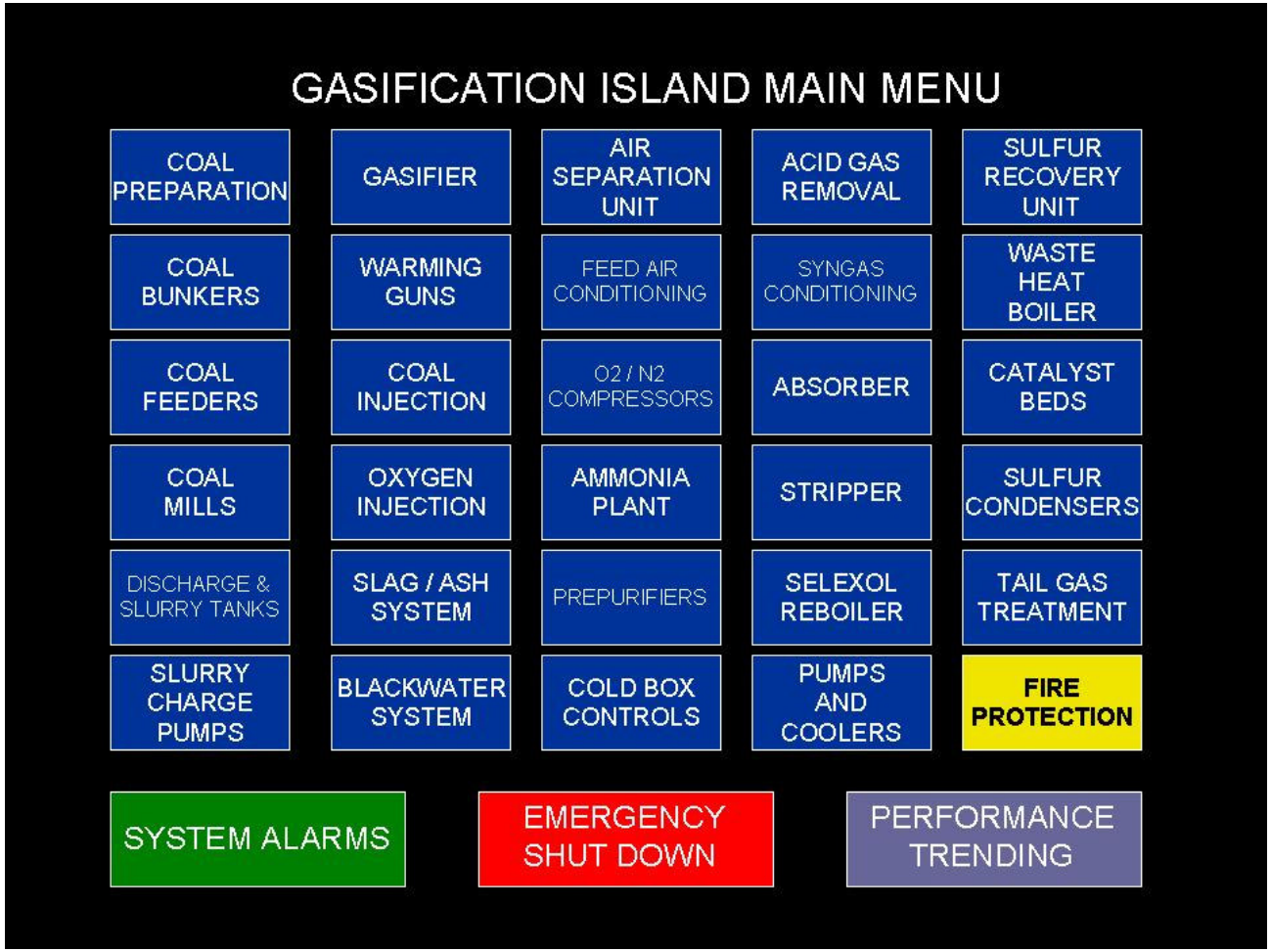
Phase II – Detailed Planning
Key Project Deliverables

- IGCC Full-Scope Simulator
- Systems Training Materials
- Integrated Operating Instructions
- Computer-Based Training Program
- Intelligent Tutoring System
- IGCC Power Plant Familiarization Course

Phase II – Detailed Planning
Data Typically Provided to OTS Vendor

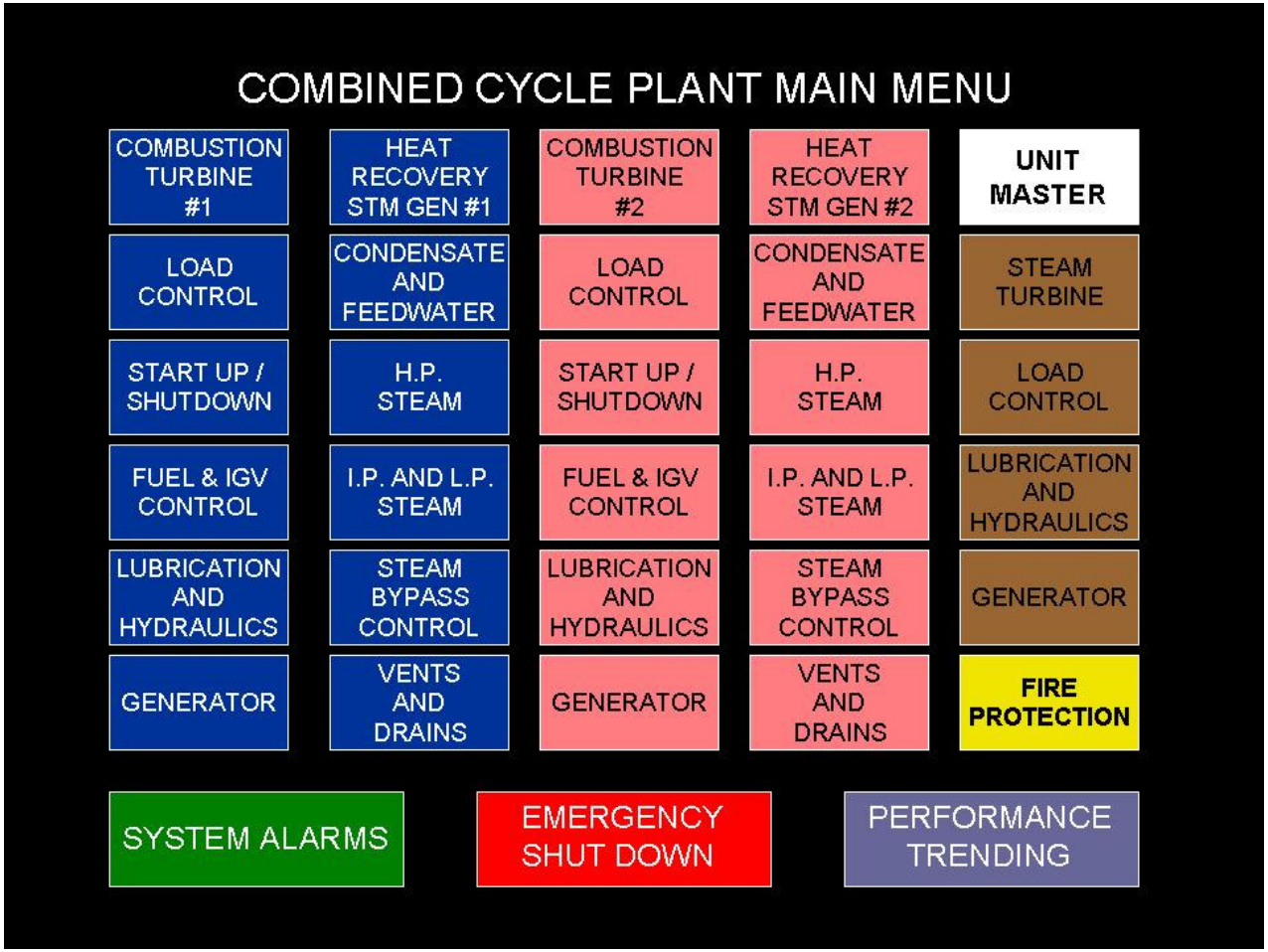
- **Systems and process descriptions**
  - Collaboration with EPRI & other technology partners
- **Equipment specifications & data sheets, P&ID's**
- **DCS graphics, control algorithms, control configuration, logic diagrams**
- **Process flow diagrams, steady-state simulation data (at varying loads & ambients)**
- **Process operating procedures**
- **Lists of upsets/malfunctions to be simulated**

Sample DCS Graphics
Gasification Main Menu



Graphic supplied courtesy of Electric Power Research Institute, Inc.

Sample DCS Graphics
Combined Cycle Main Menu



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Dynamic Simulation for IGCC Power Plants
Phases III-VI

- **Phase III: Development of Simulator**
- **Phase IV: Deployment of Training Applications**
- **Phase V: Establishment and Support of IGCC DS&T Center**
  - On-Going simulator verification/validation support
  - Establish IGCC DS&T Users Group
- **Phase VI: Development and Deployment of Custom IGCC Site-Specific Simulators**
  - Custom simulators built on well-tested technology
  - Potential significant reduction in time, cost, and technical risk for site-specific IGCC simulators

Dynamic Simulation for IGCC Power Plants

Thank You!

For additional information, please contact:

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  - TEL: 304-285-1379